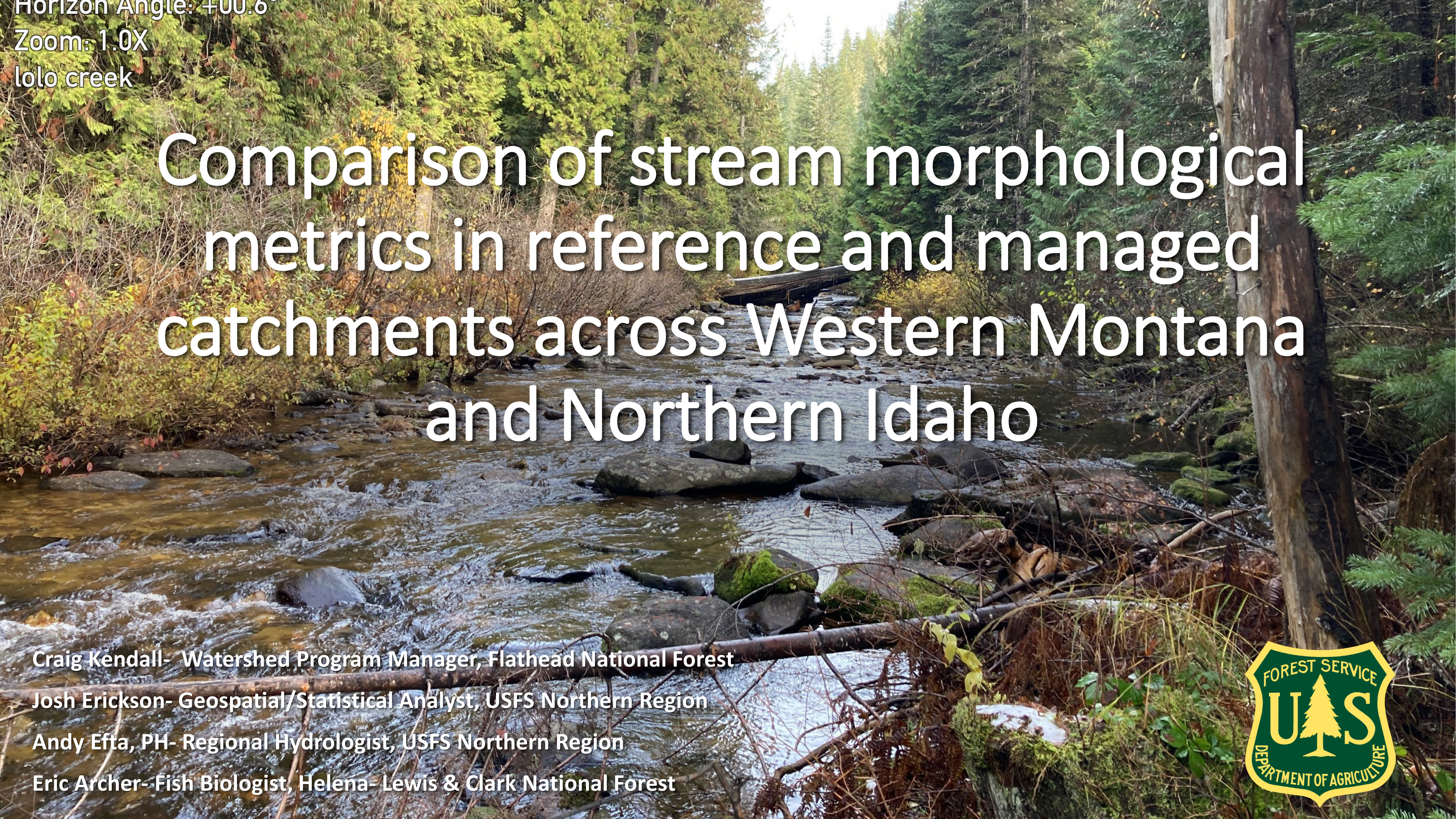
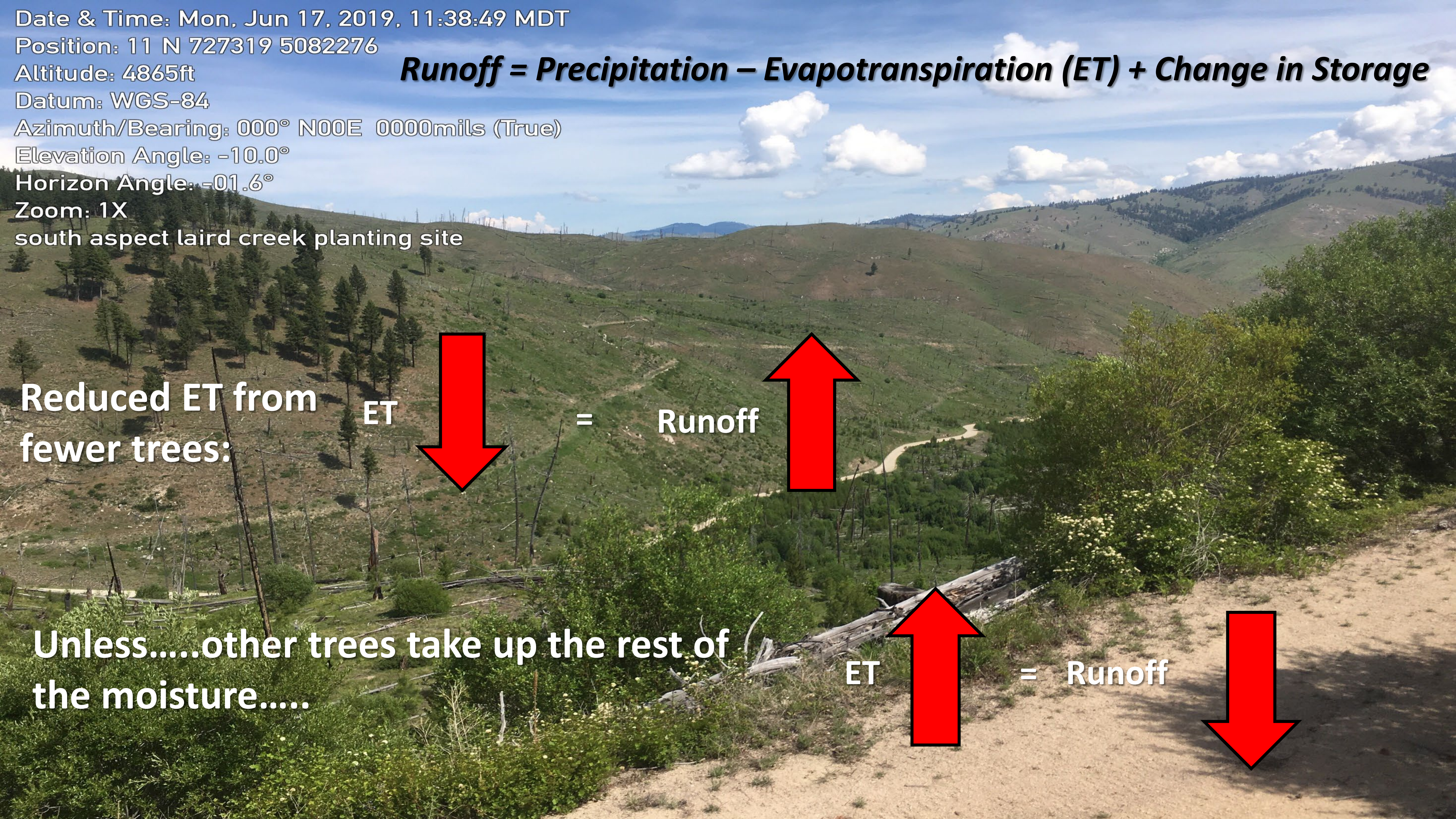


Comparison of stream morphological metrics in reference and managed catchments across Western Montana and Northern Idaho

Craig Kendall- Watershed Program Manager, Flathead National Forest
Josh Erickson- Geospatial/Statistical Analyst, USFS Northern Region
Andy Efta, PH- Regional Hydrologist, USFS Northern Region
Eric Archer- Fish Biologist, Helena- Lewis & Clark National Forest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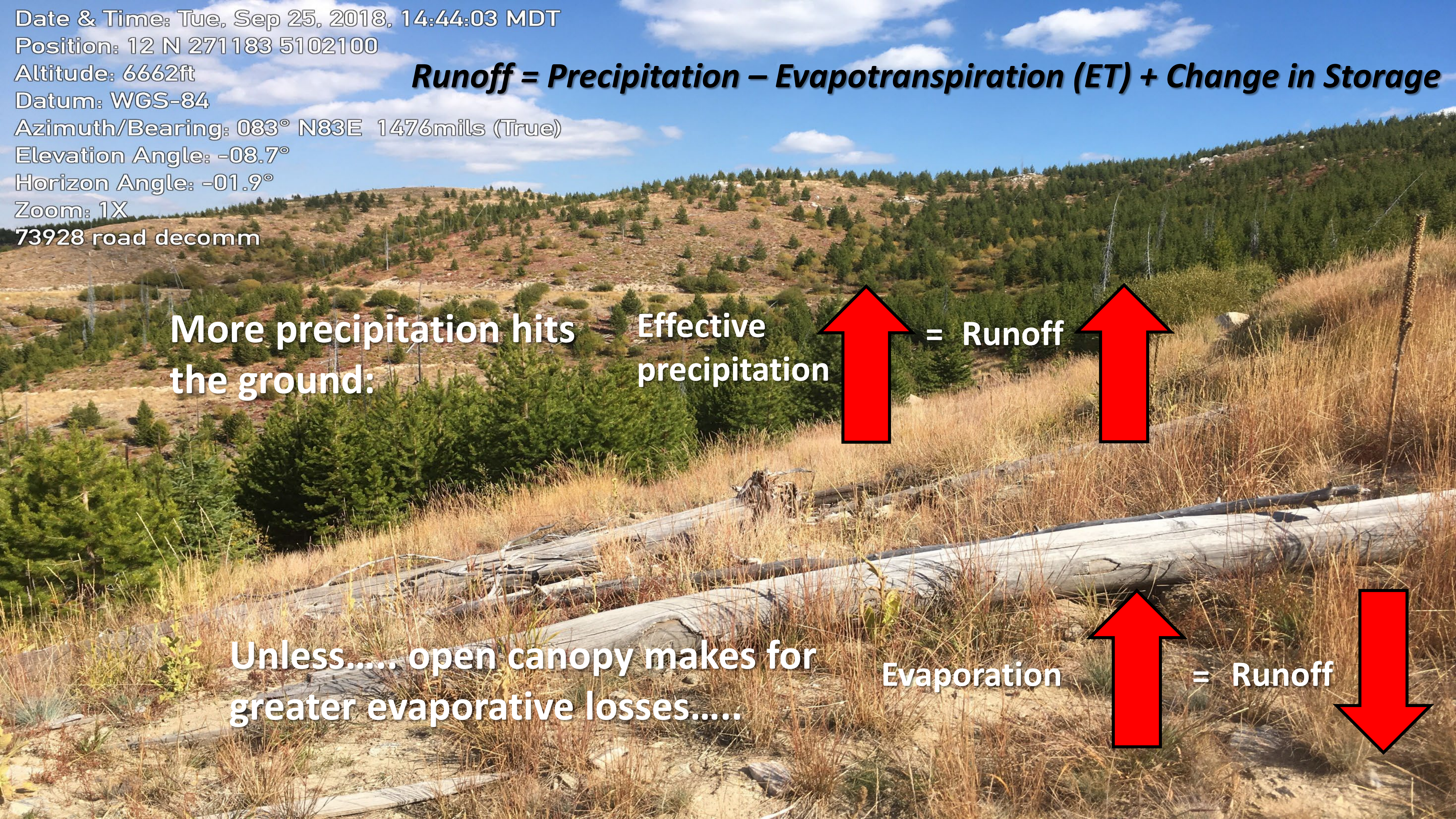
Azimuth/Bearing: 000° N00E 0000mils (True)
Elevation Angle: -10.0°
Horizon Angle: -01.6°
Zoom: 1X
south aspect laird creek planting site
Runoff = Precipitation – Evapotranspiration (ET) + Change in Storage
Reduced ET from fewer trees:
ET
=
Runoff
Unless.....other trees take up the rest of the moisture.....
ET
=
Runoff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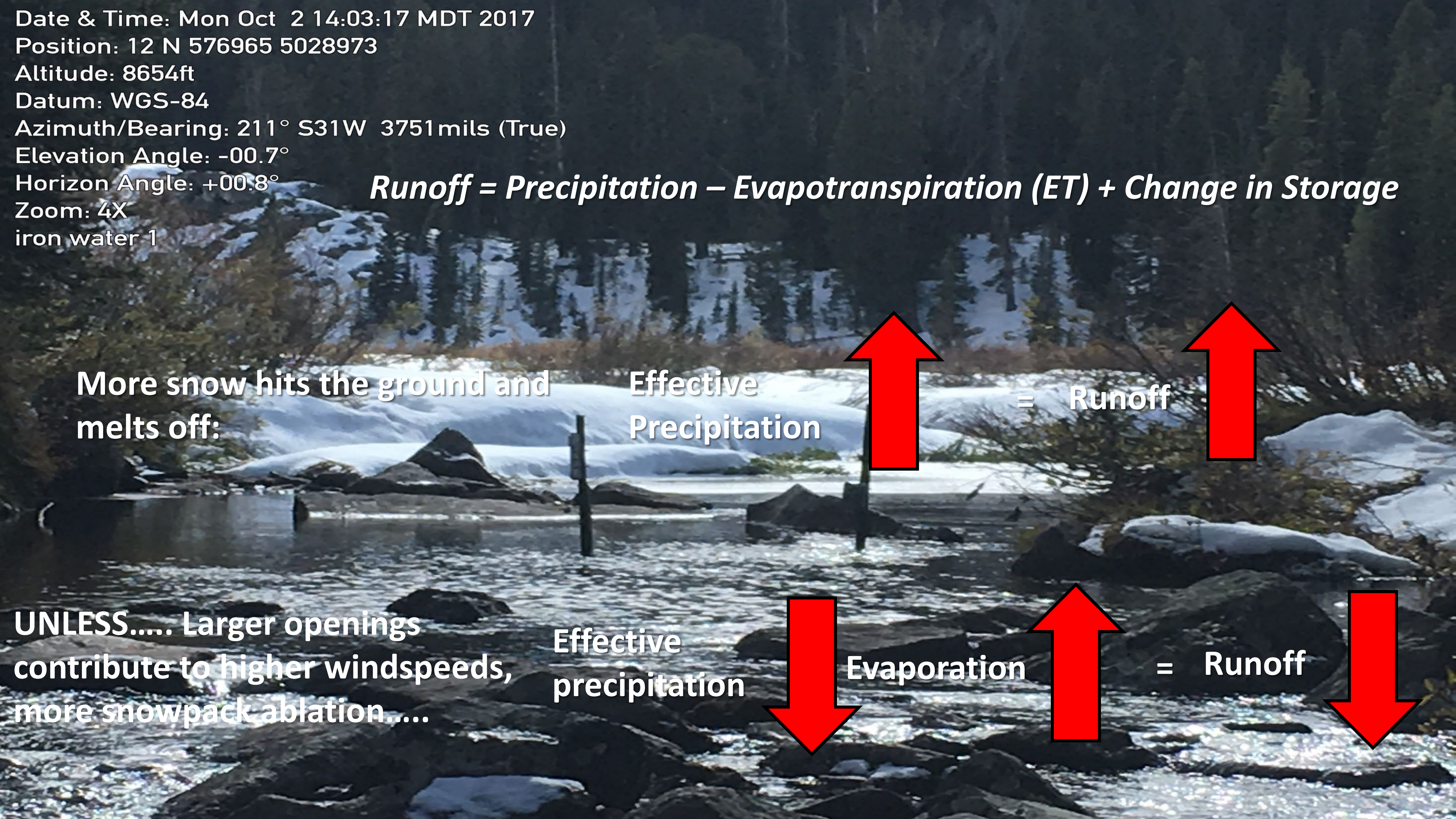
Elevation Angle: -08.7°
Horizon Angle: -01.9°
Zoom: 1X
73928 road decomm
Runoff = Precipitation – Evapotranspiration (ET) + Change in Storage
More precipitation hits the ground:
Effective precipitation
= Runoff
Unless….. open canopy makes for greater evaporative losses…..
Evaporation
= Runoff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Datum: WGS-84
Azimuth/Bearing: 211° S31W 3751mils (True)
Elevation Angle: -00.7°
Horizon Angle: +00.8°
Zoom: 4X
iron water 1
Runoff = Precipitation – Evapotranspiration (ET) + Change in Storage
More snow hits the ground and melts off:
Effective Precipitation
= Runoff
UNLESS….. Larger openings contribute to higher windspeeds, more snowpack ablation…..
Effective precipitation
Evaporation
= Runoff

What happens when we cut trees and build roads? We've known for a while….

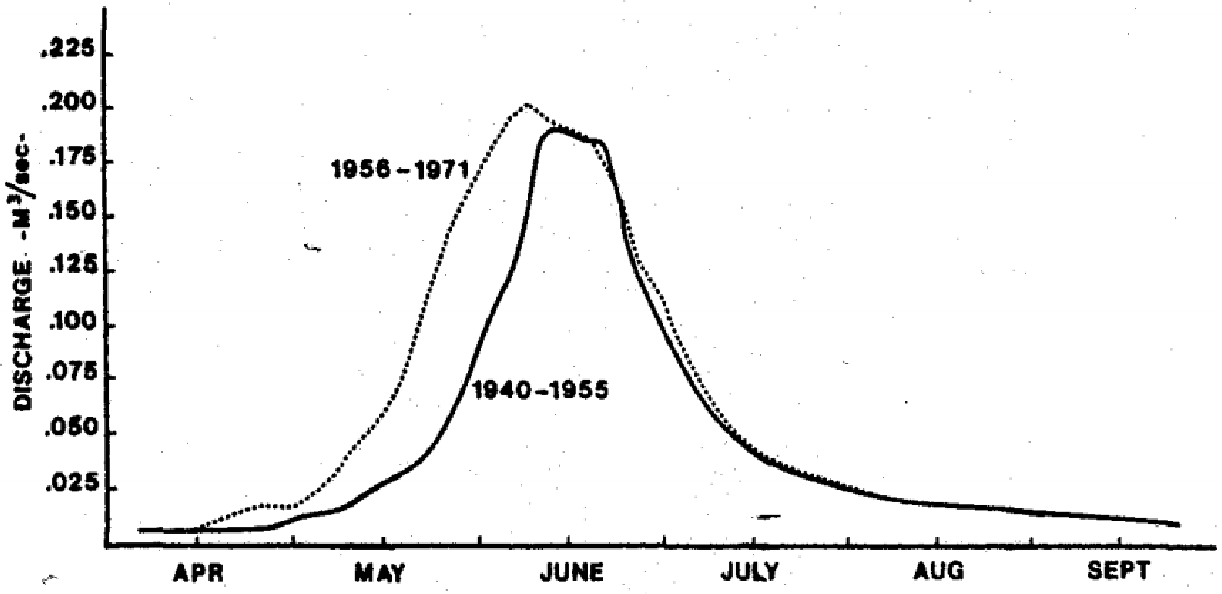


Fig. 2. Average hydrographs for Fool Creek watershed. Solid curve is average hydrography for 1940–1955, before the timber harvest; dotted curve is average hydrograph for 1956–1971, following timber harvest.

Fig. 1. Fool Creek watershed, Fraser experimental forest. Photo taken in 1958, 2 years after harvest.

(from Troendle and King 1985)

- Response is HIGHLY variable, BUT…..
- Cutting trees and building roads generally increase water yield and/or peak flows

General synopsis of effects of forest harvest on water quantity

- Approximately **20%** of forest cover must be removed to detect any change in water yield and/or peak flows
- Thinning/selective harvest tends to produce limited response
- Effects tend to get attenuated as drainage area increases
- Generally only smaller recurrence interval peak flows are affected
- Emerging recognition of “where matters”; multi-scale hydroclimatic/physiographic influences on physical water balance and flow expression

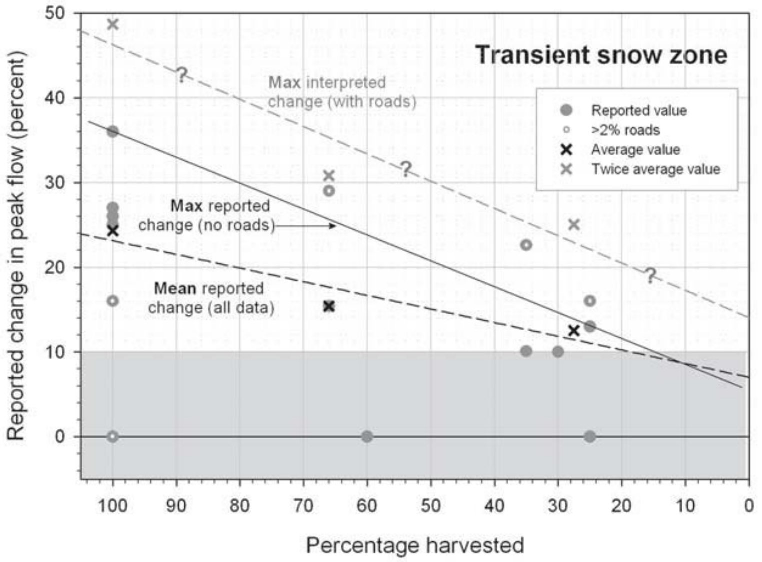


Figure and caption from Grant et al. 2008, page 35

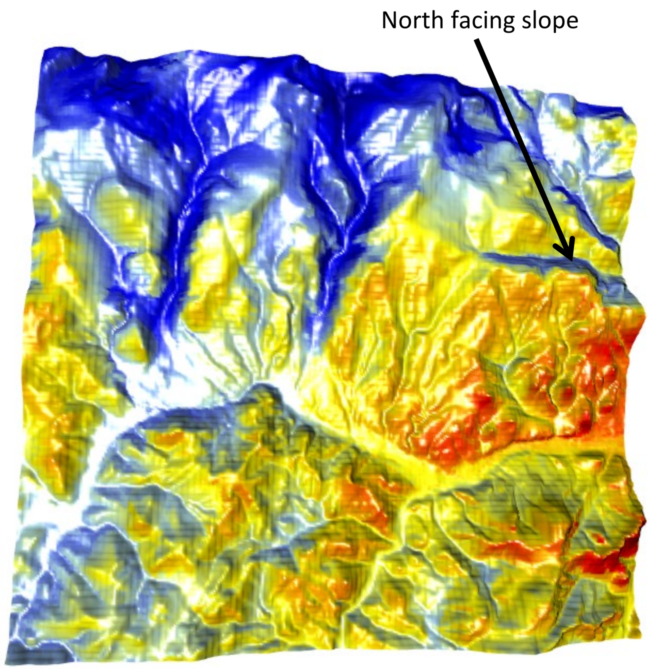


Figure credit: Z. Holden

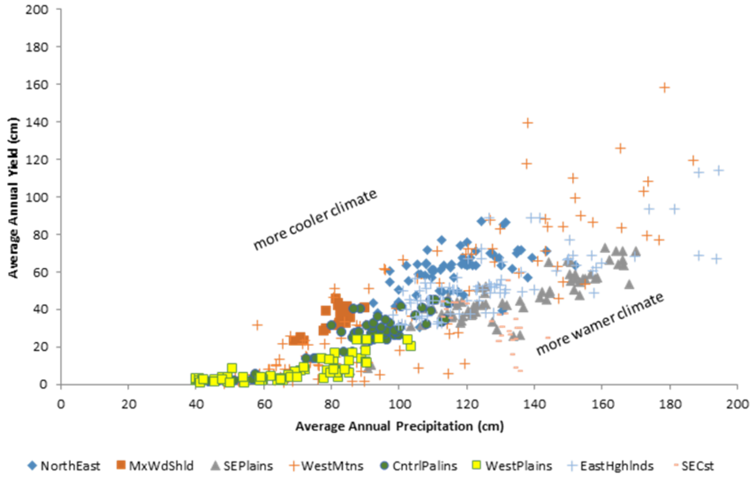
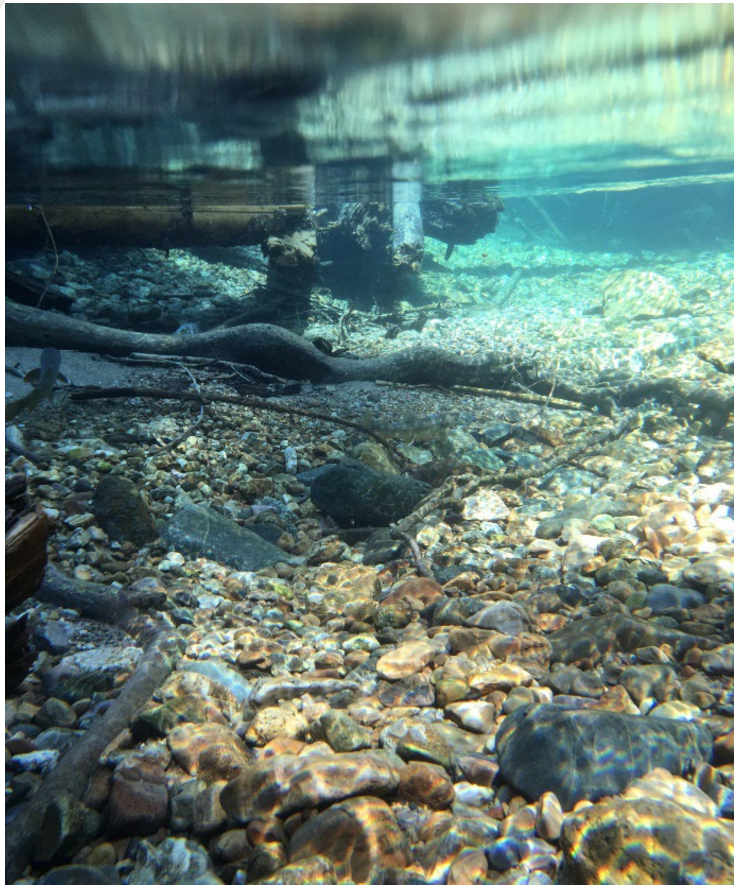


Figure credit: E. Moser

When does change matter?

- Timing and magnitude generally not concerns by themselves
- Potential for stream habitat alteration and water quality effects through stream morphological shifts
    - Channel equilibrium, effective discharge (e.g. Lane 1950, Wolman and Miller 1960, Emmett and Wolman 2001)



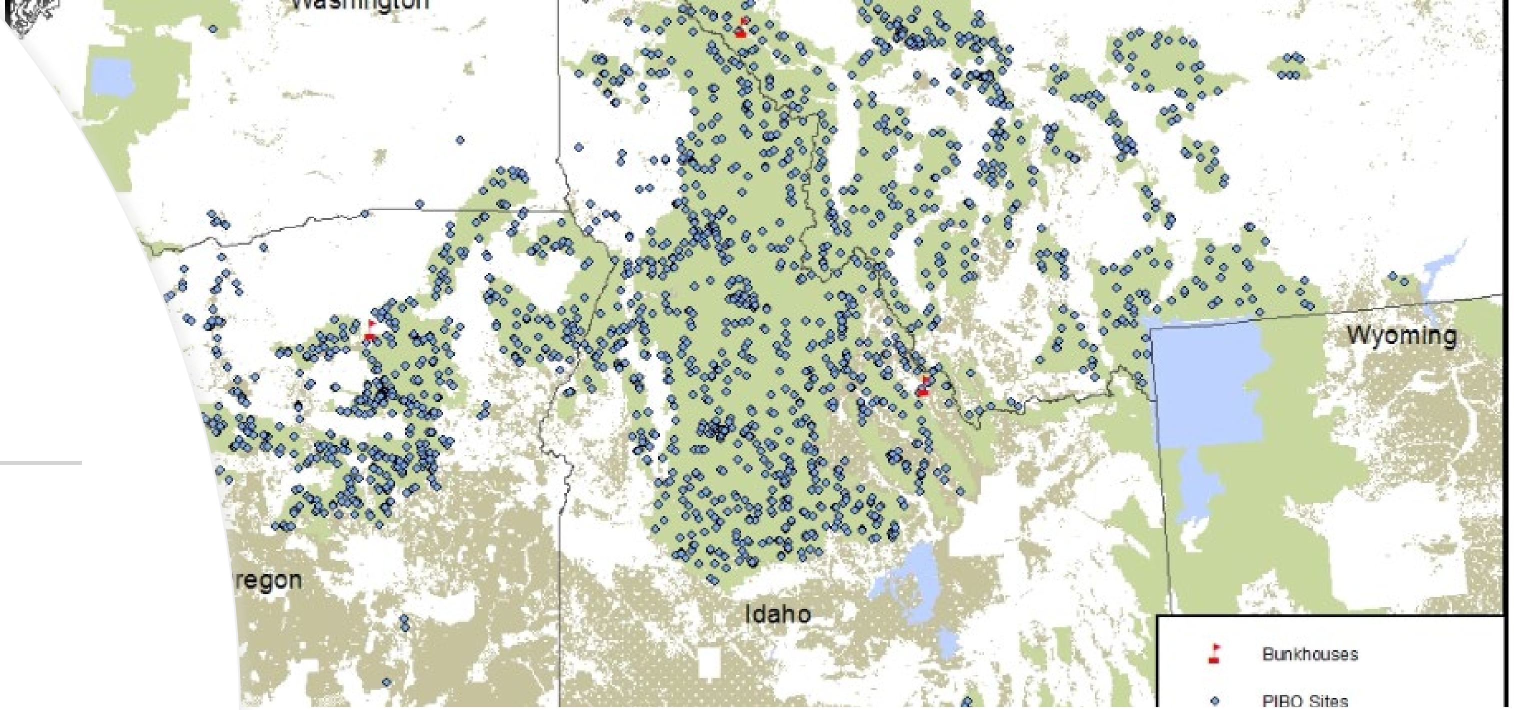
Limited research looking at channel morphological shifts from forest management

- MacDonald et al. 1995: Kootenai N.F.
  - No increase in bankfull width or width to depth ratio with more intensive management, highlighted importance of sediment supply
- Tonina et al. 2008: North Idaho modeling exercise
  - Changes in hydrograph dynamics could cause scour of bull trout spawning areas

Is forest management generating channel morphologic response in north Idaho and western Montana?

Alternative approach to exploring question

- Previous approach: Paired catchment study design
- Alternative approach: PACFISH/INFISH Biological Opinion monitoring program sites (Kershner et al. 2004)
- Sample sites throughout Columbia River Basin
- Repeat sampling on rotating panel every five years



https://www.fs.usda.gov/detail/r4/landmanagement/resourcemanagement/?cid=stelprd3845865

Study Area and Management History

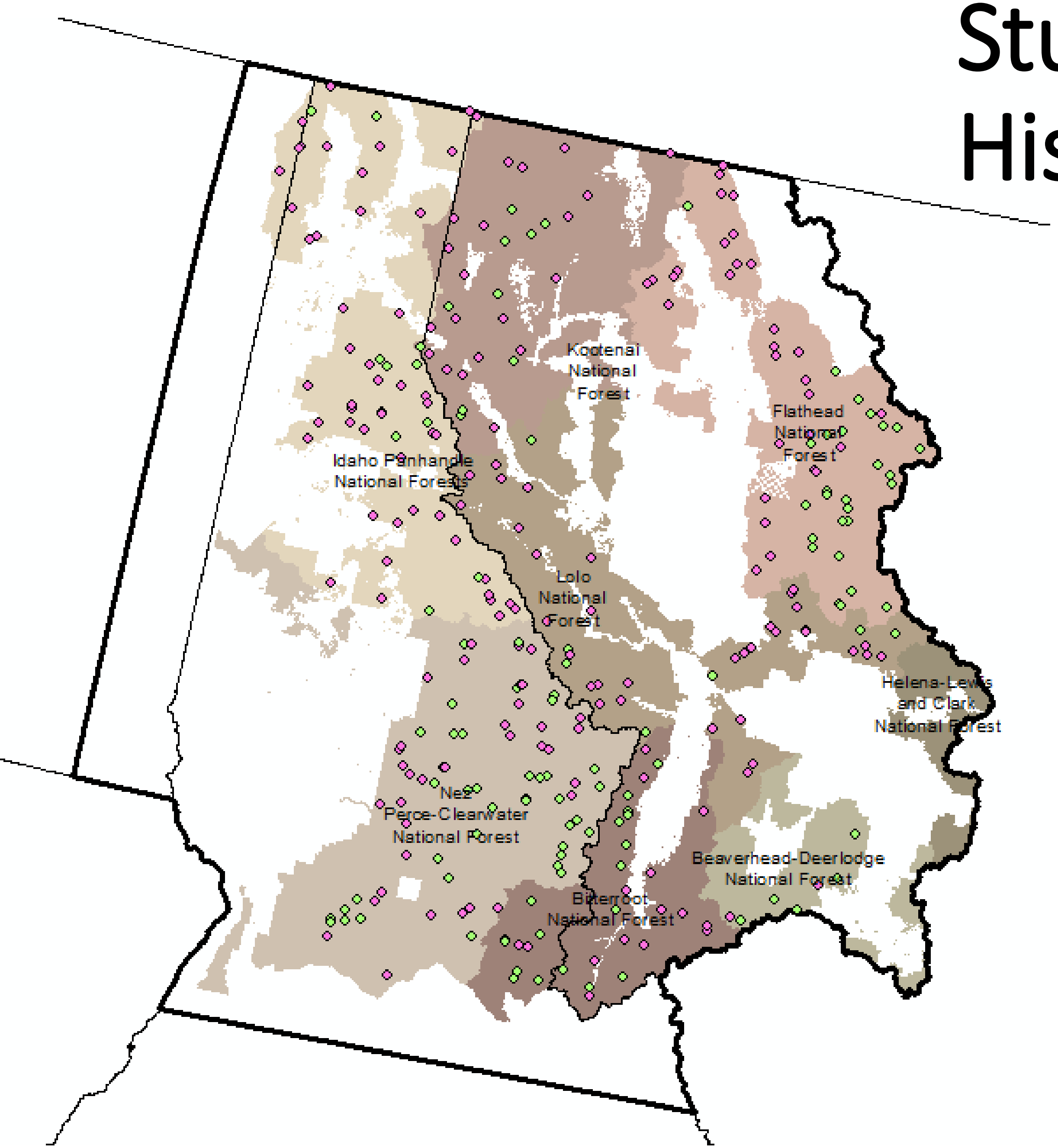
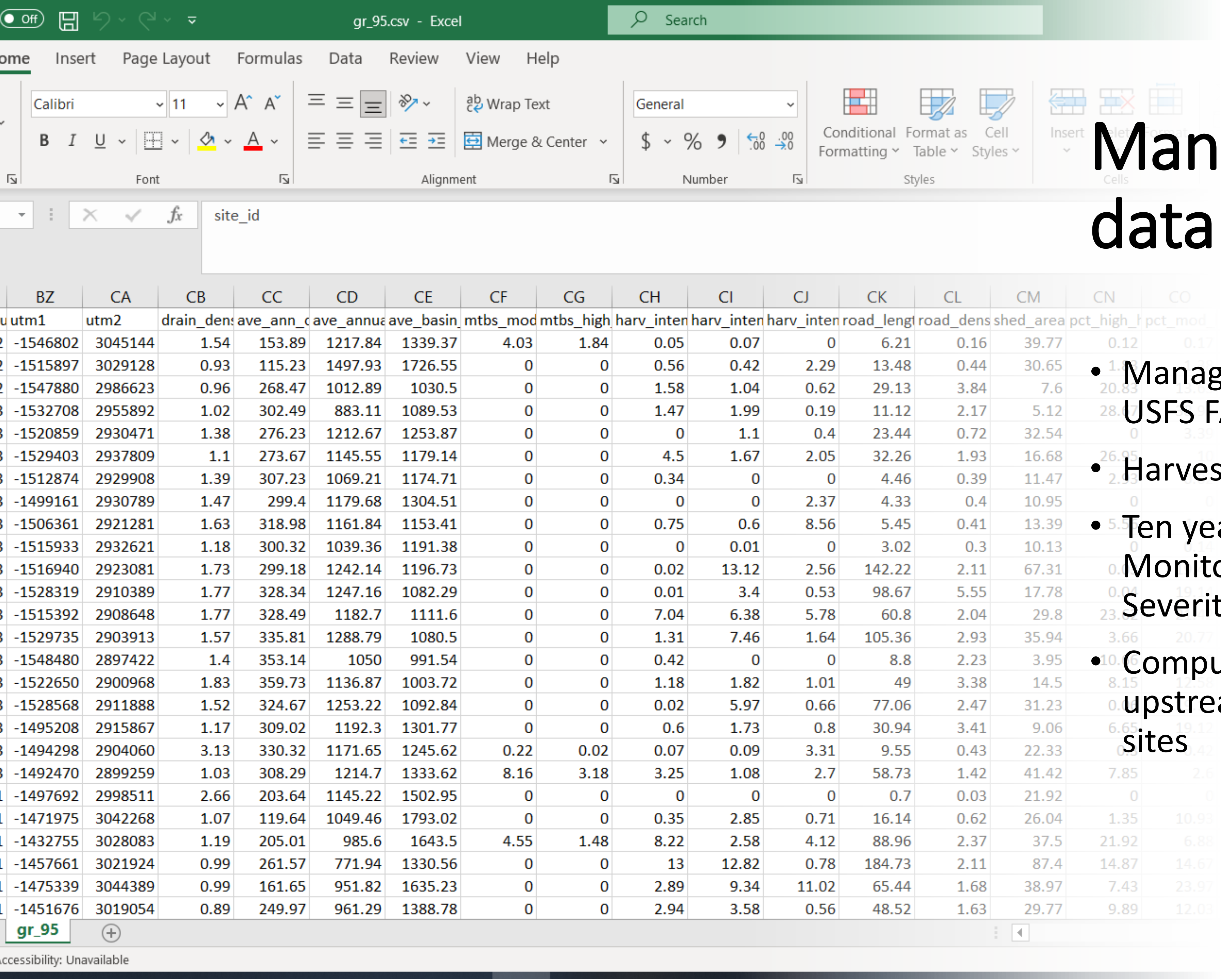


Figure 1. Study area. Reference sites are shown in green and managed sites are shown in pink.

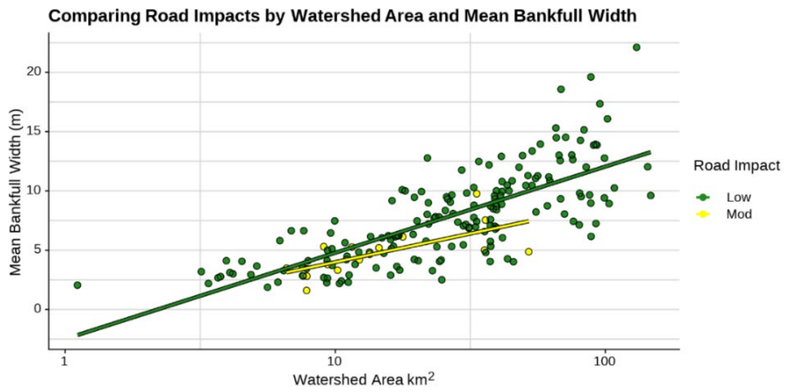
- 189 managed sites, 116 reference sites
  - Each site visited at least three times
  - Managed:
    - Timber harvest, road construction, mining
    - Timber harvest has declined substantially since the 1970s
    - Selective harvest becoming more common
- Five Level IV Ecoregions (Omernik and Griffith 2014)
- Average annual precipitation 500-2200 mm annually (Daly et al. 2008)
- Snowmelt driven and rain-on-snow peak flow events
- Drainage area ranges 1.1 km^2 – 147 km^2

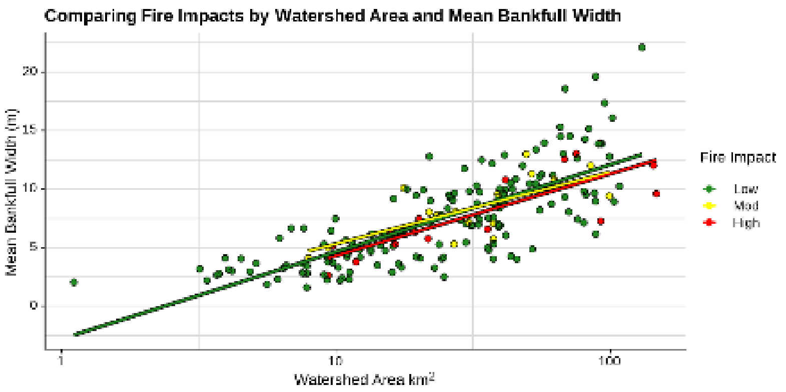
Management data sources

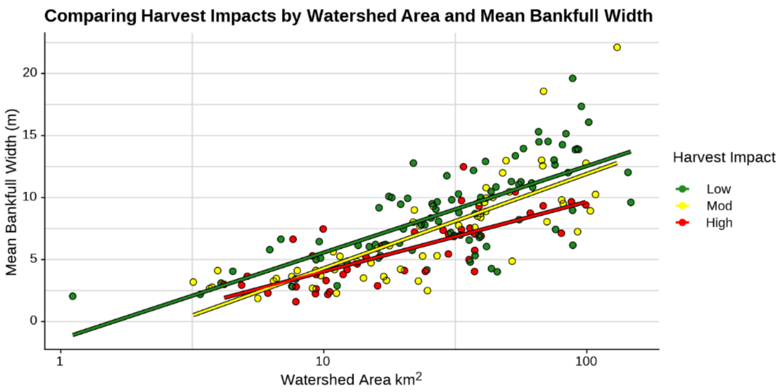


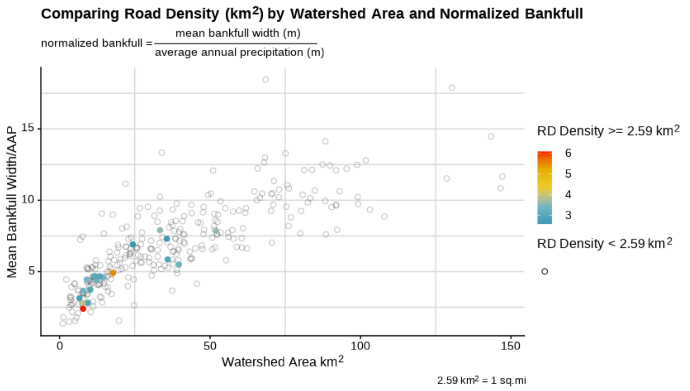
	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI	CJ	CK	CL	CM	CN	CO
u	utm1	utm2	drain_dens	ave_ann_c	ave_annua	ave_basin	mtbs_mod	mtbs_high	harv_inten	harv_inten	harv_inten	road_lengt	road_dens	shed_area	pct_high_	pct_mod
2	-1546802	3045144	1.54	153.89	1217.84	1339.37	4.03	1.84	0.05	0.07	0	6.21	0.16	39.77	0.12	0.17
2	-1515897	3029128	0.93	115.23	1497.93	1726.55	0	0	0.56	0.42	2.29	13.48	0.44	30.65	[illegible]	[illegible]
2	-1547880	2986623	0.96	268.47	1012.89	1030.5	0	0	1.58	1.04	0.62	29.13	3.84	7.6	20.83	[illegible]
3	-1532708	2955892	1.02	302.49	883.11	1089.53	0	0	1.47	1.99	0.19	11.12	2.17	5.12	[illegible]	[illegible]
3	-1520859	2930471	1.38	276.23	1212.67	1253.87	0	0	0	1.1	0.4	23.44	0.72	32.54	0	[illegible]
3	-1529403	2937809	1.1	273.67	1145.55	1179.14	0	0	4.5	1.67	2.05	32.26	1.93	16.68	26.95	[illegible]
3	-1512874	2929908	1.39	307.23	1069.21	1174.71	0	0	0.34	0	0	4.46	0.39	11.47	[illegible]	[illegible]
3	-1499161	2930789	1.47	299.4	1179.68	1304.51	0	0	0	0	2.37	4.33	0.4	10.95	0	0
3	-1506361	2921281	1.63	318.98	1161.84	1153.41	0	0	0.75	0.6	8.56	5.45	0.41	13.39	[illegible]	[illegible]
3	-1515933	2932621	1.18	300.32	1039.36	1191.38	0	0	0	0.01	0	3.02	0.3	10.13	0	[illegible]
3	-1516940	2923081	1.73	299.18	1242.14	1196.73	0	0	0.02	13.12	2.56	142.22	2.11	67.31	[illegible]	[illegible]
3	-1528319	2910389	1.77	328.34	1247.16	1082.29	0	0	0.01	3.4	0.53	98.67	5.55	17.78	0.04	[illegible]
3	-1515392	2908648	1.77	328.49	1182.7	1111.6	0	0	7.04	6.38	5.78	60.8	2.04	29.8	[illegible]	[illegible]
3	-1529735	2903913	1.57	335.81	1288.79	1080.5	0	0	1.31	7.46	1.64	105.36	2.93	35.94	3.66	20.77
3	-1548480	2897422	1.4	353.14	1050	991.54	0	0	0.42	0	0	8.8	2.23	3.95	[illegible]	[illegible]
3	-1522650	2900968	1.83	359.73	1136.87	1003.72	0	0	1.18	1.82	1.01	49	3.38	14.5	8.15	[illegible]
3	-1528568	2911888	1.52	324.67	1253.22	1092.84	0	0	0.02	5.97	0.66	77.06	2.47	31.23	[illegible]	[illegible]
3	-1495208	2915867	1.17	309.02	1192.3	1301.77	0	0	0.6	1.73	0.8	30.94	3.41	9.06	6.65	19.12
3	-1494298	2904060	3.13	330.32	1171.65	1245.62	0.22	0.02	0.07	0.09	3.31	9.55	0.43	22.33	[illegible]	[illegible]
3	-1492470	2899259	1.03	308.29	1214.7	1333.62	8.16	3.18	3.25	1.08	2.7	58.73	1.42	41.42	7.85	[illegible]
1	-1497692	2998511	2.66	203.64	1145.22	1502.95	0	0	0	0	0	0.7	0.03	21.92	0	0
1	-1471975	3042268	1.07	119.64	1049.46	1793.02	0	0	0.35	2.85	0.71	16.14	0.62	26.04	1.35	10.93
1	-1432755	3028083	1.19	205.01	985.6	1643.5	4.55	1.48	8.22	2.58	4.12	88.96	2.37	37.5	21.92	6.88
1	-1457661	3021924	0.99	261.57	771.94	1330.56	0	0	13	12.82	0.78	184.73	2.11	87.4	14.87	14.67
1	-1475339	3044389	0.99	161.65	951.82	1635.23	0	0	2.89	9.34	11.02	65.44	1.68	38.97	7.43	[illegible]
1	-1451676	3019054	0.89	249.97	961.29	1388.78	0	0	2.94	3.58	0.56	48.52	1.63	29.77	9.89	12.03

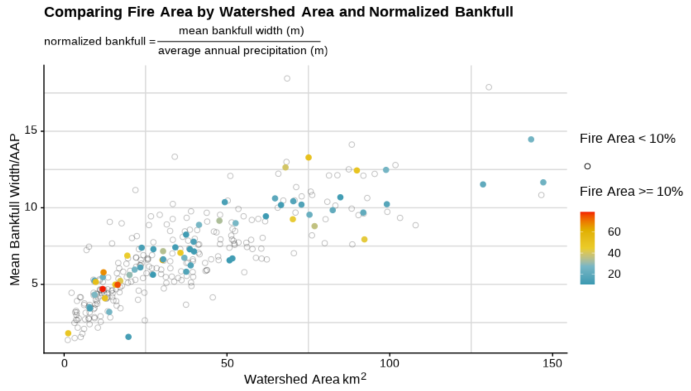
- Management data pulled from USFS FACTS database
- Harvest intensity stratified
- Ten years of fire data- Monitoring Trends in Burn Severity (MTBS)
- Computed road densities upstream of PIBO monitoring sites

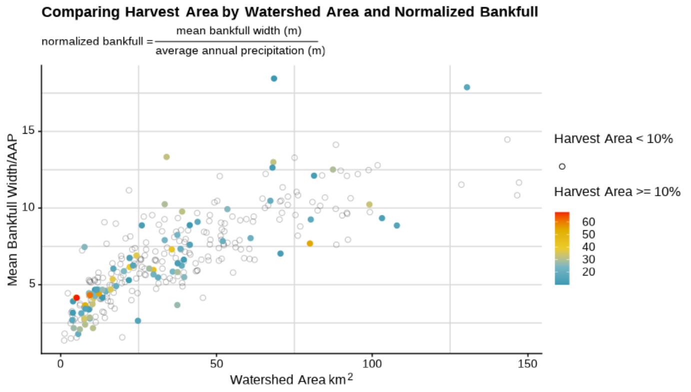












EDA and ANCOVA

- Graphical and statistical analyses yielded no discernable and/or significant differences between management variables and channel geomorphic variables (bankfull width, width to depth ratio, bank angle)
- BUT…Indirect effects AND Time not accounted for

Statistical analysis (cont.)

- Dependent variables:
  - Bankfull width
  - Bankfull width to depth ratio
  - Bank angle
- Performed backward feature selection (stepwise AIC) with spatial cross validation using ecological sections to identify covariates for each dependent variable
- Linear Mixed Effects Regression (LMER)

Covariate	Data source	Literature Reference
Catchment area	USGS National Elevation Dataset	Sando et al. 2018
Mean basin elevation	USGS National Elevation Dataset	Sando et al. 2018
Average annual precipitation (1981-2010)	PRISM Climate Group, Oregon State University	Daly et al. 2008
Mean basin slope (percent)	USGS National Elevation Dataset	Sando et al. 2018
Annual mean daily maximum temperature (1981-2010)	PRISM Climate Group, Oregon State University	Daly et al. 2008
Mean annual climatic water deficit (1981-2010)	Montana Climate Office, US Forest Service Region 1	Hoylman et al. 2019
Topographic Wetness Index	USGS National Elevation Dataset	Beven and Kirkby 1979; Sando et al. 2018

Table 1. List of covariates derived from gridded data sources used to evaluate bankfull width, bankfull width: depth ratio, and bank angle.

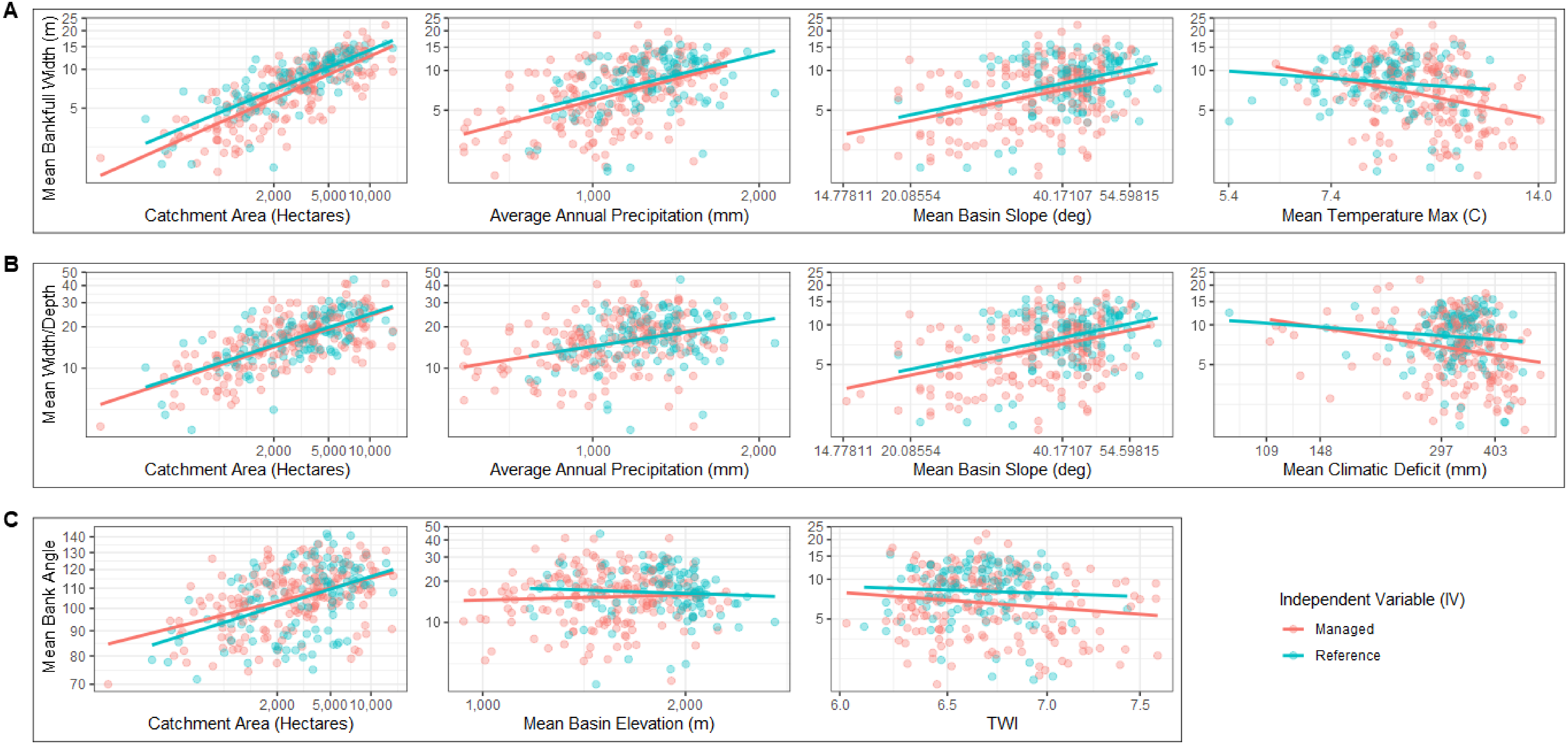


Figure 2. Covariates selected during pre-processing steps for the LMER model framework, by Dependent Variable: A) bankfull width, B) width/depth ratio, and C) bank angle. Points are site means, not repeated measures. Site means were used for covariate selection to limit correlation bias. Figure tiles have been stratified by Independent Variable and linearly regressed.

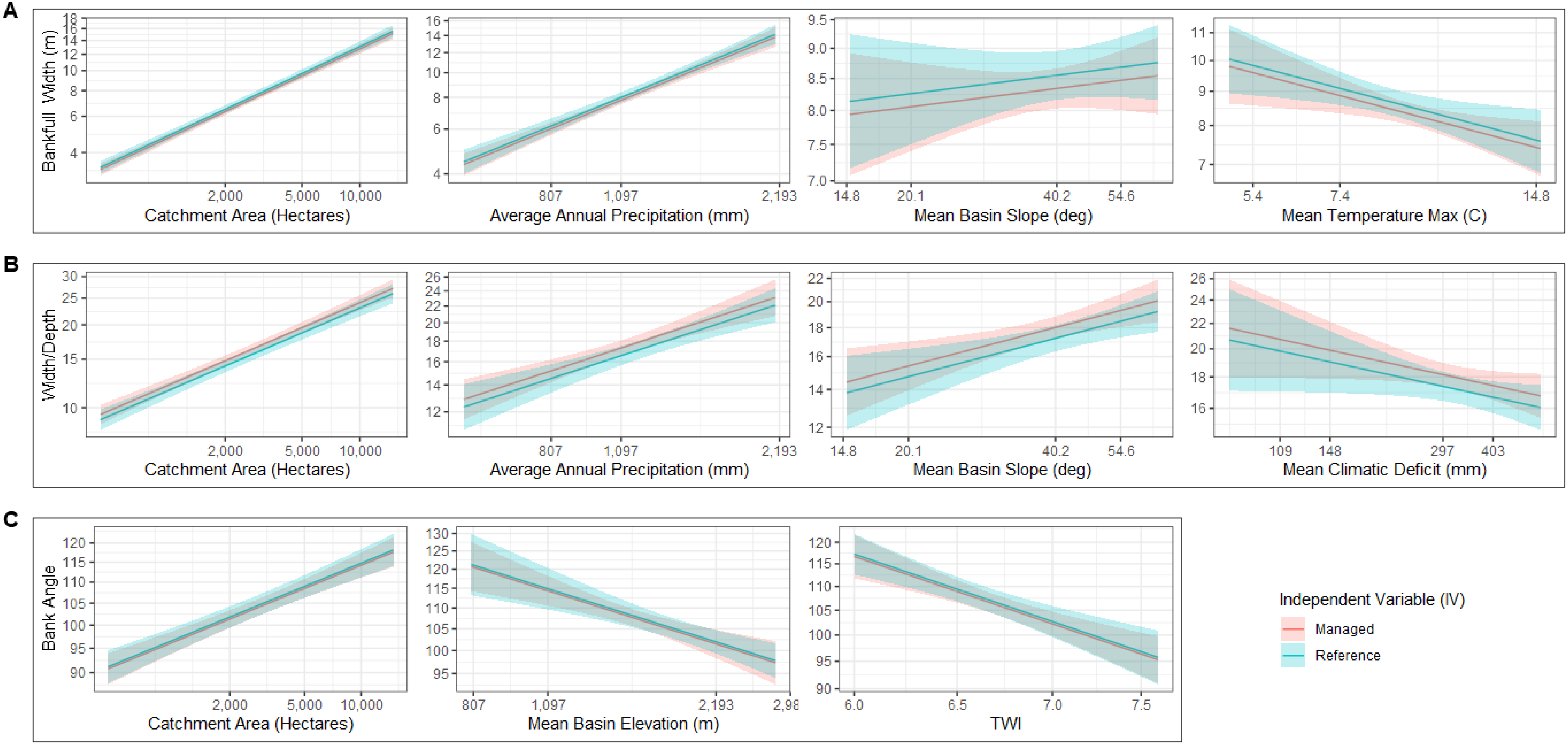


Figure 3. Marginal effects per covariate from the final LMER model by Dependent Variable: A) bankfull width, B) bankfull width/depth, and C) bank angle. Figure tiles have been stratified by the Independent Variable and include 95% confidence intervals (cooler and warmer ribbons). While one covariate is varying (x-axis), the others are being held constant allowing a marginal effect (prediction) to be made.

Results

- Failed to detect statistically significant differences in response variables in reference and managed groups
- If management-induced morphologic shifts have occurred, our results suggest that they cannot be detected within the bounds of inherent ecoregional variability

Limitations

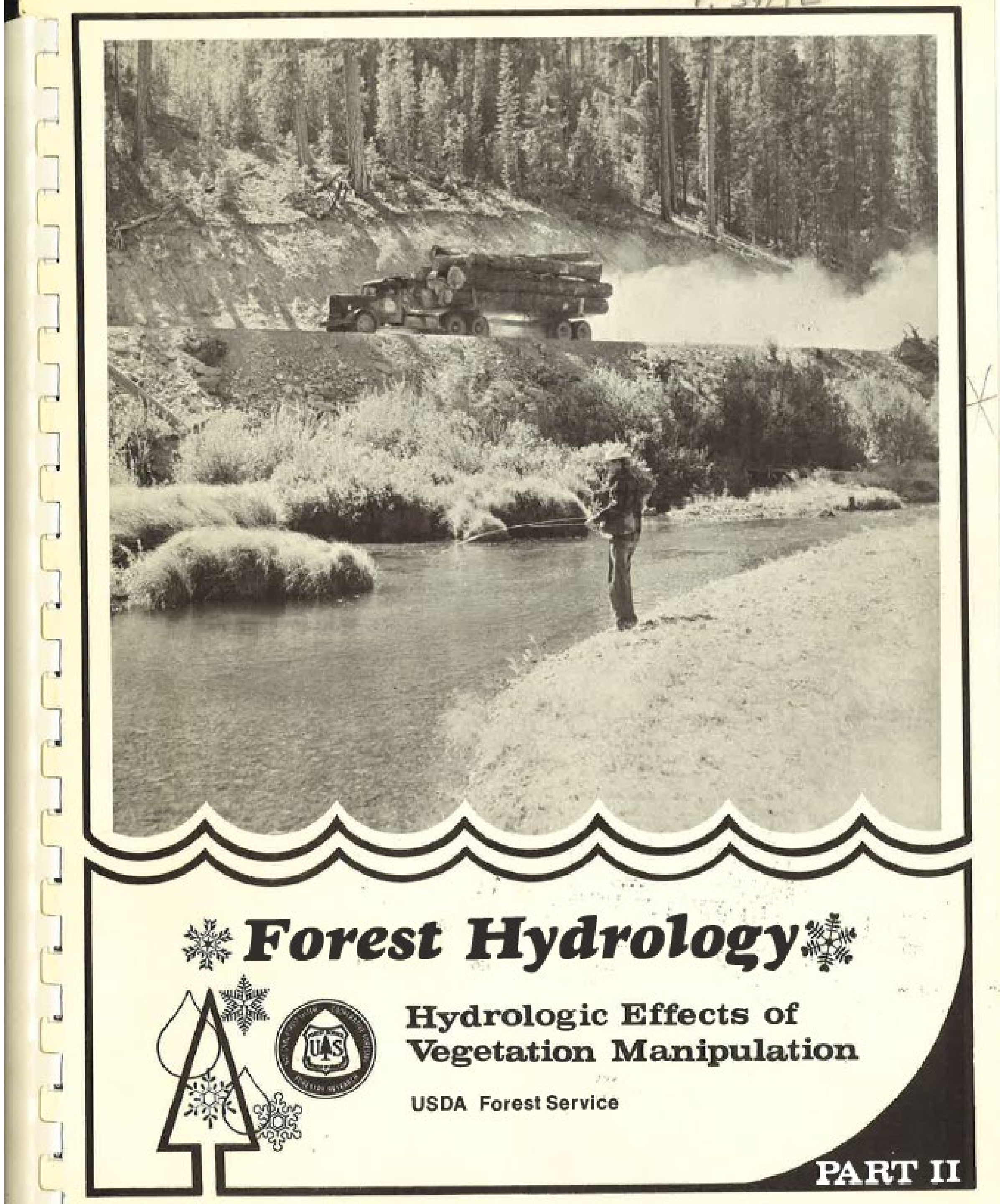
- Can’t make direct tie to forest management; indirect effects
- Limited number of harvested acres in managed catchments
  - Between 1989-1999 and 2009-2019: “Green” harvest declined by 70%
- Low frequency of high intensity harvest
- Detection of management effects on channel morphology metrics depends on the magnitude of effect and sample size
- Wide range of drainage areas, hydroclimatic variation, and management characteristics
  - Differing hydrologic and geomorphic drivers have influence at differing scales

Conclusions

- Study made use of larger sample size and spatial domain than used in the past to evaluate channel morphologic changes
- Findings shed light on level of detectability of management-induced channel changes resulting from hydrograph shifts
- Results affirm that landscape characteristics (i.e. catchment area, precipitation, topographic relief, etc.) play a primary role in shaping bankfull channel dimensions in the study area; management-related differences could not be detected

Management implications

- Water quantity change is near-ubiquitous planning issue…but should it be?
  - NEPA
  - Clean Water Act
  - Endangered Species Act
- Recommend further analyses of sediment effects on instream channel habitat metrics associated with forest management activities



Questions?

- Acknowledgements:
    - Carl Saunders and Brett Roper: USFS Rocky Mountain Research Station
    - Kelsey David, USFS Geospatial Specialist